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LUMINARY Memo #144

To: Distribution
From: D. Eyles
Date: 6 April 1970
Subject: Variable Servicer Tests

This memo is to report on a series of tests run using the new Variable Guidance Period Servicer developed in off-line version ZERLINA, described in references 1 and 2, and formally proposed in PCR 1024. I should say immediately, to whet appetites, that a successful landing was made with 20% TLOSS. A landing with 30% TLOSS, although it suffered some alarms, also reached the surface with aplomb.

By the time this memo reaches its readers a revision of ZERLINA will be available suitable to be exercised by anyone equipped with a simulator who wants to give it a whirl.

The tests described here are all landings. Tests of the P40s, the P70s, and P12 are under way and will be described separately by Sharon Albert who is helping me. At least one of each category has run successfully already. For each test I describe I am including plots of guidance period (PGUIDE), dutycycle, and activity. These are the plots most of ten mentioned in the text because they best illustrate the operation of the Variable Servicer. These plots are concentrated at the end so the text can be read more easily. Also available in a limited edition are plots of thrust and the three CDU angles for the first six tests enumerated below. The avid student can use these to convince himself that at least in the cases tried ZERLINA's performance compares with that of the nominal LUMINARY run.

The principal runs mentioned in this memo are these:

I.   LUMINARY 154. Landing without terrain (real or modeled) and no TLOSS - for comparison purposes.

II.   ZERLINA 16. Landing without terrain or TLOSS.

III.   ZERLINA 16. Like run II but with minimum guidance period (PGMIN, normally 2 seconds) set to 1 second.

IV.   ZERLINA 16.   Like run II but with 20% TLOSS.

V.   ZERLINA 16.   Like run II but with 30% TLOSS.

VI.   ZERLINA 16.   Like run II but with terrain and terrain model. Repeated on ZERLINA 17.

VII.   ZERLINA 16.   Like run II but with redesignations in P64 and a Noun 69 site update in P63.

VIII.   ZERLINA 17.   Landing like VI (with terrain) with 10% TLOSS and V16 monitors in P63 and P66.

In addition I ran numerous shorter tests as rollbacks of I (for comparison), II, and IV with redesignations and lateral velocity noise spikes near the end of P64, and exercises of P66 Auto. These were "shot-tests" designed to reveal latent instability in P64 or P66. No instability was excited. To reduce the bulk of this document I am saving these for analysis later.

Below are plotted the landing sites reached by tests I through VI and test VIII. They lie within 200 feet of each other. Test VII landed some distance away from this traffic jam thanks to redesignations.
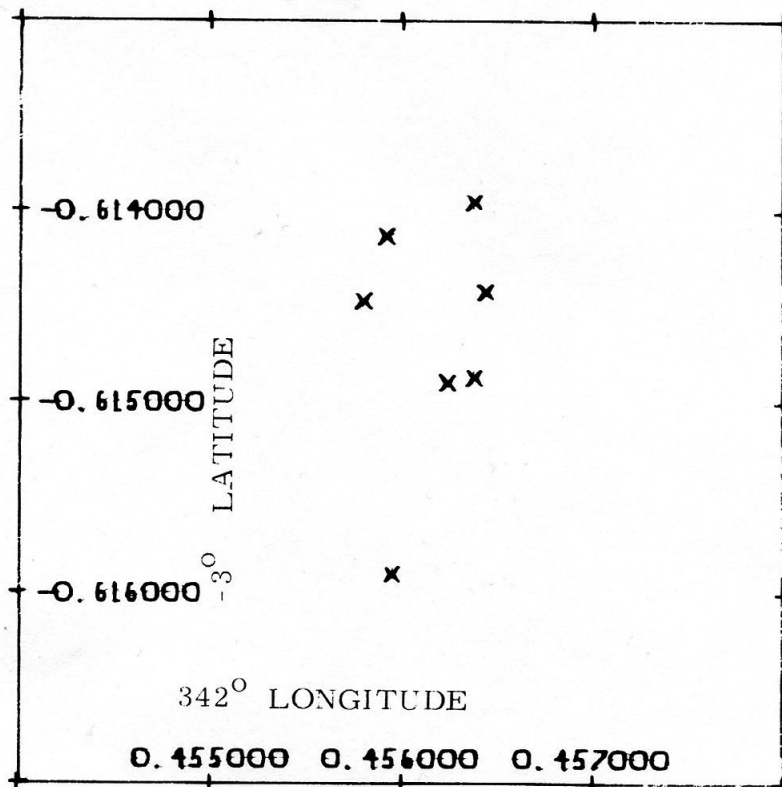
On the next page is a numerical comparison of tests I through VI.

	I. LUM	II. ZER	III. ZER	IV. ZER	V. ZER	VI. ZER
Throttle-down						
T:	388720.76	388721.23	388720.42	388720.59	388722.70	388721.19
TTF:	-164.19	-163.76	-164.36	-164.25	-162.63	-163.69
Higate *						
T:	388824.76	388825.31	388824.81	388825.71	388824.85	388825.32
TTF:	-60.78	-60.35	-60.70	-59.94	-60.82	-60.22
H:	7178 feet	7095 feet	7130 feet	7020 feet	7159 feet	7480 feet
HDOT:	-168.9 ft/s	-168.4 ft/s	-168.4 ft/s	-168.2 ft/s	-166.9 ft/s	-177.9 ft/s
Logate **						
T:	388968.76	388969.37	388967.82	388971.47	388972.28	388969.49
TTF:	-10.70	-10.71	-11.69	-10.24	-9.38	-11.13
H:	99 feet	99 feet	101 feet	99 feet	94 feet	99 feet
HDOT:	-2.5 ft/s	-2.3 ft/s	-2.6 ft/s	-2.4 ft/s	-2.2 ft/s	-2.0 ft/s
Landing						
T:	389006.95	389002.64	388999.77	389003.35	389008.08	388993.63
LAT:	-3.61590°	-3.61487°	-3.61413°	-3.61442°	-3.61395°	-3.61490°
LONG:	342.45595°	342.45638°	342.45592°	342.45644°	342.45638°	342.45624°
RLS:	1650600 meters	1650596 meters	1650597 meters	1650602 meters	1650602 meters	1650594 meters
	-522034	-522036	-522036	-522034	-522023	-522034
	-109434	-109432	-109412	-109427	-109426	-109432
RCS:	24.46 lbs.	24.34 lbs.	23.59 lbs.	22.83 lbs.	25.02 lbs.	21.78 lbs.
ΔV:	6672 ft/s	6639 ft/s	6623 ft/s	6652 ft/s		6609 ft/s
Passes:	364	362	470	302	about 240	357

* Last pass in P63.   ** Last pass in P64.

Test I will be mentioned as a comparison for the ZERLINA tests. Dutycycle and activity for this run are plots 1 and 2.

Test II.   This was the simplest case ZERLINA landing.   Plot 3 shows PGUIDE. Since PGMIN was the normal 2 seconds and ZERLINA's dutycycle never exceeds that, PGUIDE for this run is a nearly uniform 2 seconds.   The minor variations visible are what happens when higher priority jobs, such as keystrokes, happen to be in progress when the Servicer job is re-awakened by the Minimum Period Logic.   These variations are of no consequence. Plots 4 and 5 are dutycycle and activity plots for this test.   If the duty cycles of LUMINARY and ZERLINA are compared at equivalent points they give an idea of the magnitude in time of the additional computations involved in the Variable Servicer.   Actually with PGMIN = 2 seconds the dutycycle of ZERLINA is about the same as that for LUMINARY 1C (plot 6) -- with the difference that when ZERLINA uses up its margin its performance is scarcely affected.   What happens when LUMINARY 1C uses up its margin readers of Klumpp's 16 page compendium (reference 3) are well aware.

Test III.   This test was made to reveal the landings "natural" guidance period: how fast it runs when not restrained by the Minimum Period Logic. Thus PGMIN was set to a low value: 1 second.   Plot 7 shows that PGUIDE is not interfered with once the landing guidance is connected at THRUP.   The shape of this PGUIDE plot should closely resemble the shape of the dutycycle plots for tests I and II (plots 1 and 4) -- and it does.   The higher PGUIDEs between 40KFT and 30KFT show where V57 was executed to turn on the landing radar.   The jaggedness of PGUIDE during P66 shows that during some guidance periods two P66ROD jobs are executed while during others only one occurs. P66ROD runs independently of Servicer at 1 second intervals, as modified in ZERLINA revision 7.

Note that PGUIDE is always significantly less than 2 seconds.   It has been mentioned as a drawback of the Variable Servicer, by Norton in reference 4, that "by allowing the computations to exceed the previous maximum of two seconds, the minimum cycle time is also increased."   However the plot of PGUIDE with PGMIN = 1 second proves that the minimum cycle time with no TLOSS is below two seconds, and this being the case it is hard to see how any drawback is involved, at least in comparison with LUMINARY. For the practical minimum guidance period of ZERLINA to exceed 2 seconds

(LUMINARY's maximum and minimum) computations would have to be added to the Servicer loop over and beyond the additional landing radar incorporation coding, which is complete in this test. If computations of the same length were added to the Servicer loop in LUMINARY either the loop would be disabled or the TLOSS margin would be decreased to an unacceptably small value. This is an argument in favor of a Variable Servicer.

The dutycycle plot for test III (plot 8) shows no time remaining once guidance is connected. In other words all the time available is being used, and as a result there were 470 passes through Servicer in this run compared to 364 in the LUMINARY run. The activity plot for test III (plot 9) is just like that for test II except that DELAYJOB is used less because the Minimum Period Logic is not forcing delays.

Test IV. This test was a good landing with 20% TLOSS. There were no alarms. The PGUIDE plot (plot 10) for this run is an amplified version of that for test III. PGUIDE was roughly 3.5 seconds during P66. This is of no consequence to the rate-of-descent equation which always runs at 1 second intervals, but it does slow down the attitude-command or horizontal-velocity-nulling part of P66. Rollbacks indicate that although the P66 Auto equation is slower with this TLOSS it is not unstable. That at 20% TLOSS PGUIDE approaches but does not exceed 4 seconds and P66 Auto is still stable together give a first indication that 4 seconds is a sensible, or at least neat, choice for PGMAX. It is the value at which a landing with 20% TLOSS squeaks through without an alarm. The dutycycle and activity plots for this run (11 and 12) show the same patterns as those for tests II and III. This is evidence that a high TLOSS does not cause any degeneration into a helter-skelter mode of operation.

Test V. This interesting run was made as a sadistic torture test of the Variable Servicer logic. TLOSS was 30%. It was meant to show up any logical flaws at very high TLOSS, not necessarily to land safely. PGMAX was set to 6 seconds from the usual 4 to reduce the number of 555 alarms issued by the Maximum Period Logic. As it turned out once a faulty throttle computation was patched a successful landing was made with 30% TLOSS. There were 9 32000 alarms during P63 and P64. This alarm (with software restart) is issued when the DAP overlaps itself -- when a new TIME5 interrupt occurs before the processing initiated 100 ms. before by the

previous TIME5 rupt has concluded. With the Servicer loop taken care of the DAP loop is the next to protest. Although there has been little testing of the DAP in this situation -- for the very good reason that the Servicer loop always broke down first -- it did not loose control. That these DAP alarms did not occur more often suggests that 30% TLOSS is about the value at which they begin to appear. Thus until the DAP is tested with these very high TLOSSes 25% or 30% must be regarded as the TLOSS margin of Variable Servicer ropes.

In this run four 555 alarms were issued during P66. As plot 14 shows, PGUIDE reached about 7 seconds during this phase. The rate-of-descent loop continued to run at about 1 seconds, and since it contains a state extrapolation which makes it independent of Servicer for long periods its commands were not impaired. But the P66 Auto equation was processed only once every 7 seconds. If it were thought necessary to provide operationally for this monstrous case the astronaut would null horizontal velocity himself (using the cross-pointers which are still reliable) instead of using P66 Auto. He would know to do this himself if alarm 555 occurred. And the ground, who by subtracting successive PIPTIMEs knows PGUIDE and can compare it with simulated values, could probably tell him sooner.

If the activity plot for this run (16) is compared to that for runs II through IV again no significant differences are observed, except some effects attributable to the software restarts. V57 was executed three times in this run to be sure of turning on the landing radar in spite of the software restarts which kill extended verbs. This accounts for the two extra periods of higher vac area and core set usage and for the extra spikes in PGUIDE in P63.

Test VI shows that the Variable Servicer is not upset by terrain variations. But primarily it shows that the terrain model works. This was in fact the first test of the terrain model coding and uses ranges and slopes I brewed up for the occasion. ZERLINA's pioneer image is enhanced by the fact that it flew the first successful landing over the Fra Mauro terrain without either Noun 69 redesignations or a large DELQFIX.

Test VII proves that the redesignator works in ZERLINA (of course) and exercises the Variable Servicer under at least slightly different conditions than any other run.

Test VIII. This was an exercise of the Variable Servicer with terrain, 10% TLOSS and, on top of that, monitor verbs in P63 and P66. Plot 18 shows that PGUIDE exceeds 2 seconds for two periods in P63. The first is when V57 is executed. The second is when V16N92 is entered for 25 seconds. Once P64 begins, with this TLOSS, PGUIDE hovers near 2.2 seconds. Near the start of P66 a radar drop out occurs so incorporations are skipped, but simultaneously V16N92 is keyed in so PGUIDE stays greater than PGMIN. When key release is performed and the monitor vanishes PGUIDE drops to 2 seconds, only to jump up again when the radar data good bits reappear. An occasional spike in PGUIDE marks where three P66ROD jobs occur instead of the usual two during one Servicer cycle. This run shows how PGUIDE responds to astronaut DSKY activity and how, unlike LUMINARY, ZERLINA lets one play with the DSKY even during P66.

Conclusion. In these tests ZERLINA demonstrates (1) performance equal to that of LUMINARY in the absence of time loss, (2) its indifference to time loss in the range zero to 20% and its tolerance --not without protest -- of higher TLOSS still, and (3) that it accepts time loss due to DSKY activity just as nonchalantly. In as much as the tests run are of the level 5 variety, they indicate that a release qualified rope containing the Variable Guidance Period Servicer and all powered flight programs modified to match could be sent to Raytheon in May. Because the changes involved lie mostly within the powered flight "subroutine" FLY, this change could most easily be incorporated into LUMINARY simply by calling subroutine ZFLY (ZERLINA's version) instead of FLY.

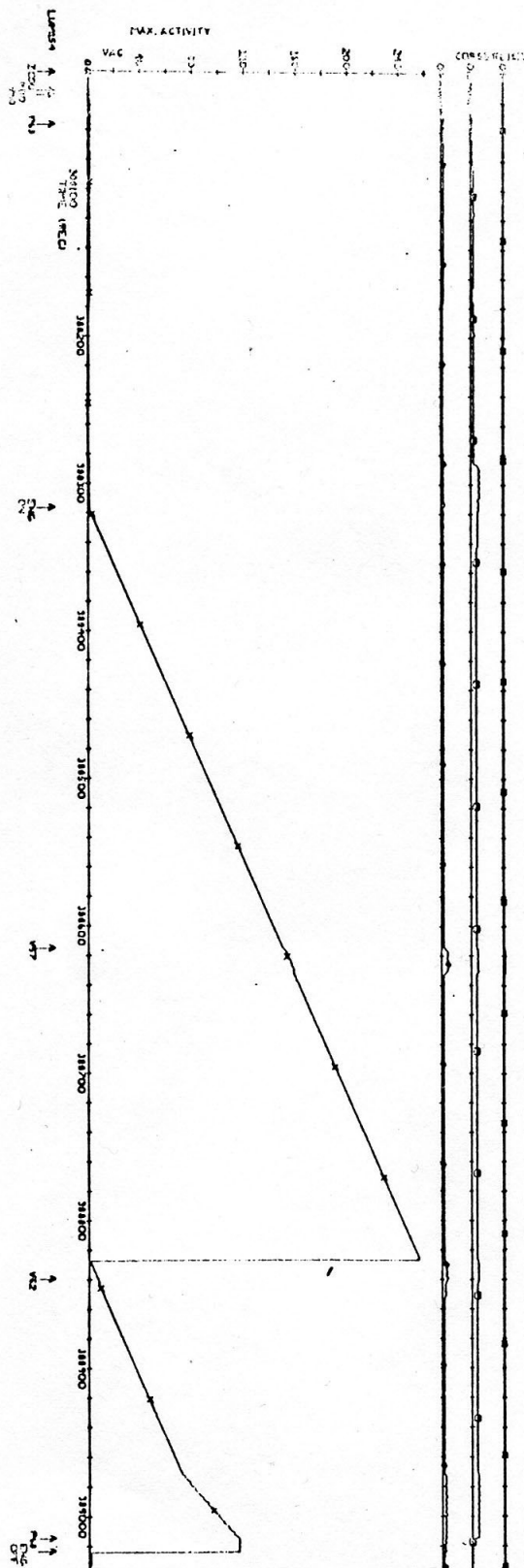ZERLINA is what you've been waiting for, folks.

LUMINARY 154 LANDING: NO TLOSS
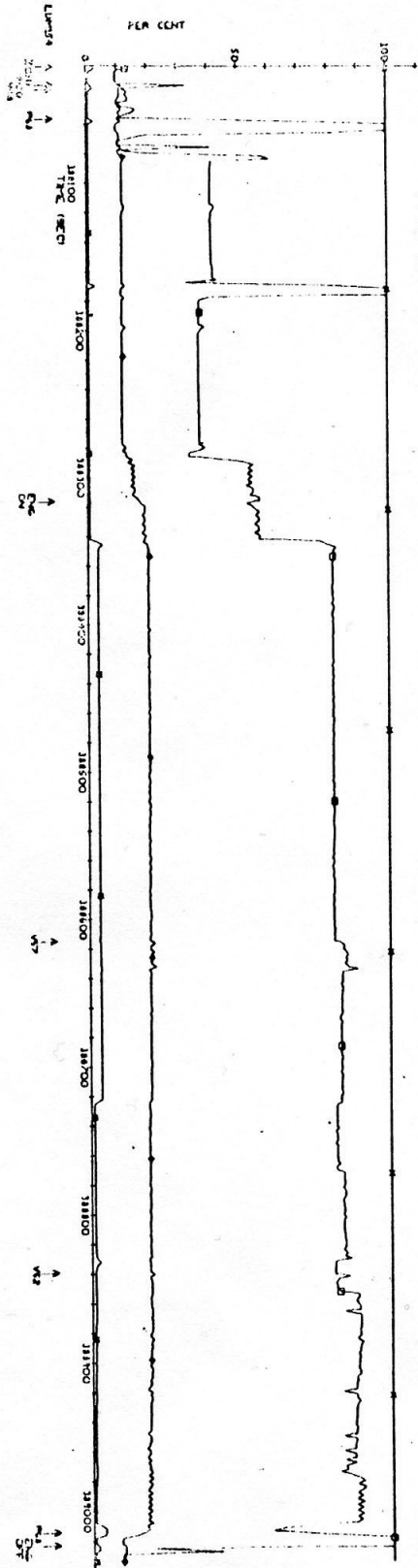
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GUIDANCE PERIOD

MARSROT NUMBER 08706095
ZERLINA 16 LANDING NOMINAL WITHOUT TERRAIN

③

SECONDS

-1 0 1 2 3 4

Event labels:
- AVGON
- P63 ENGON
- THRUP
- 50KFT
- 40KFT
- 30KFT
- THRDWN 20KFT
- 10KFT
- P64 5000FT
- 1000FT 500FT
- P66 ENGOFF TDOWN
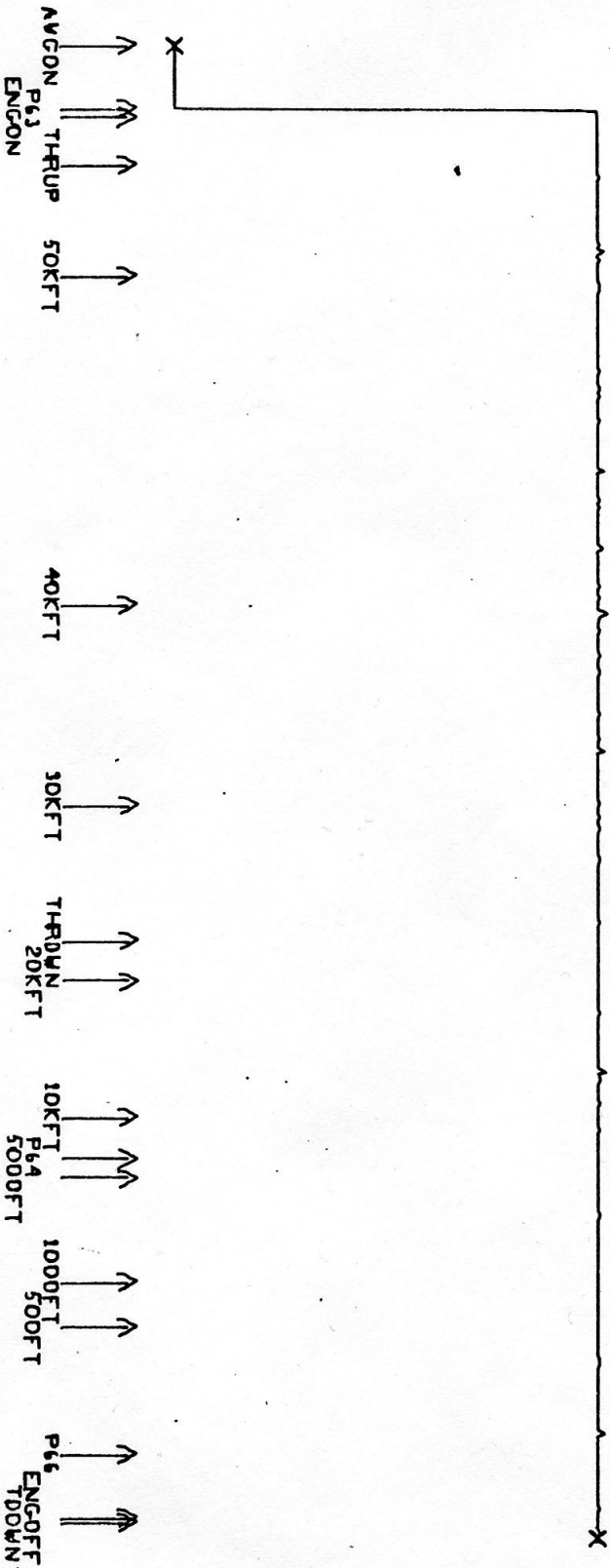
SECONDS G.E.T.

388300 388400 388500 388600 388700 388800 388900 389000

AE

ZERLINA LANDING: NO TLOSS

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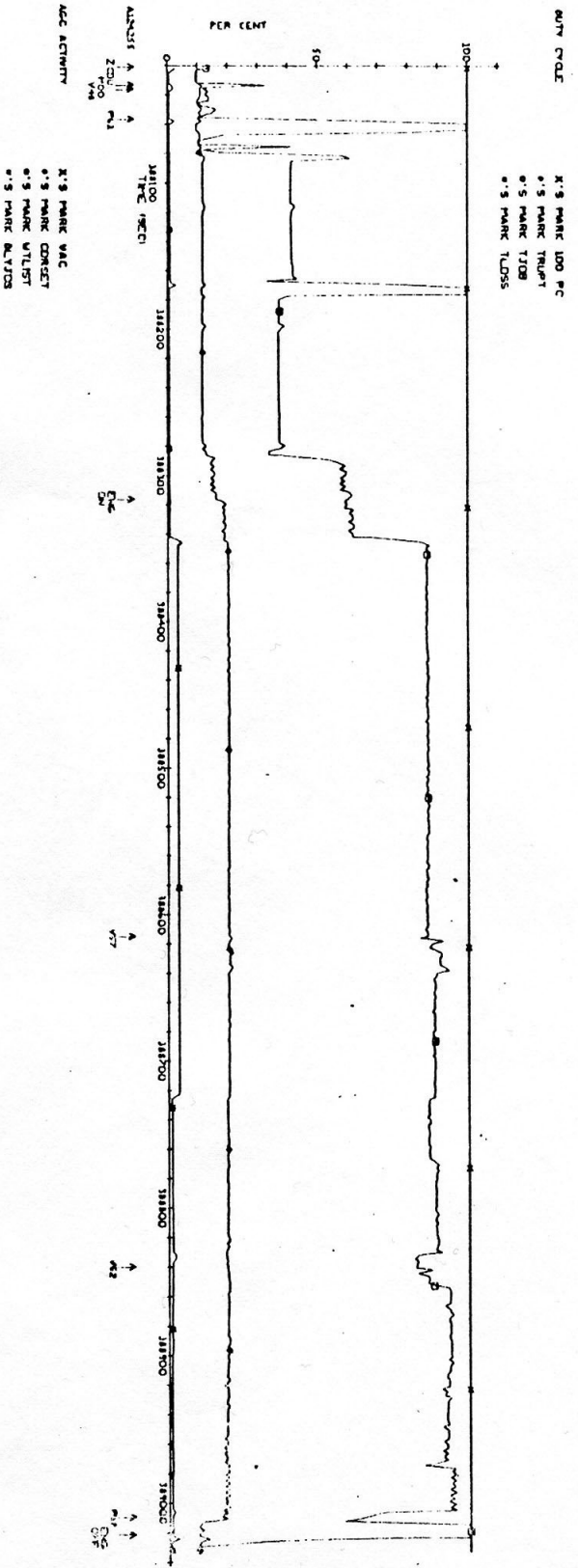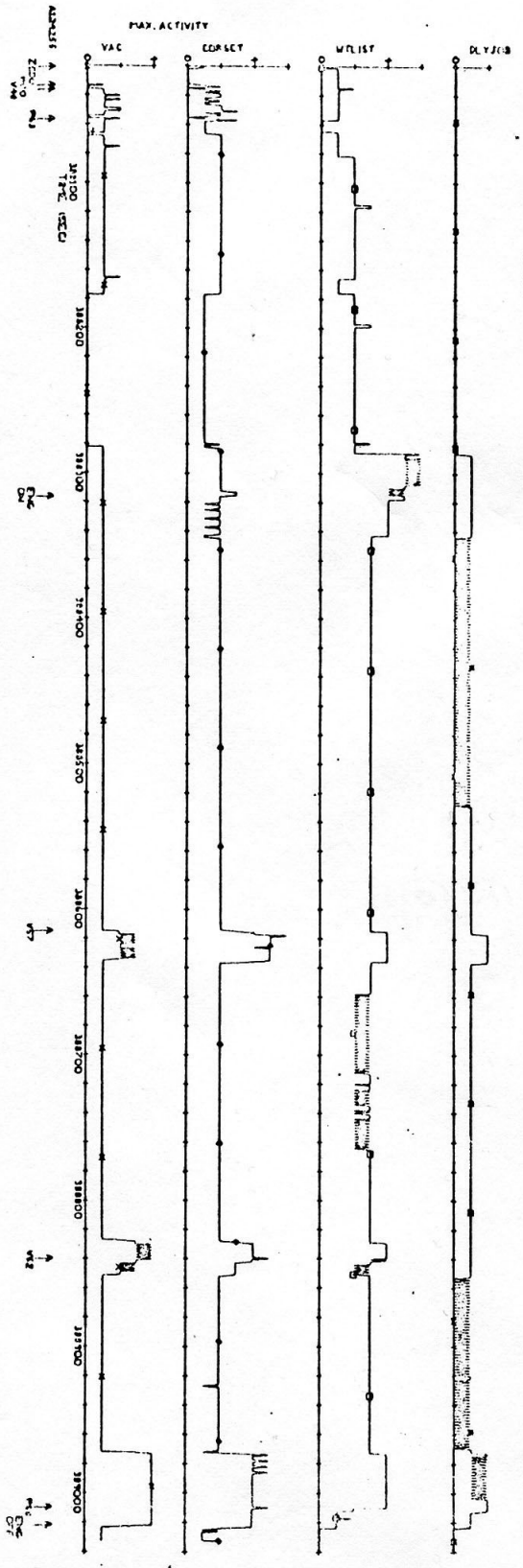
LUMINARY IC LANDING
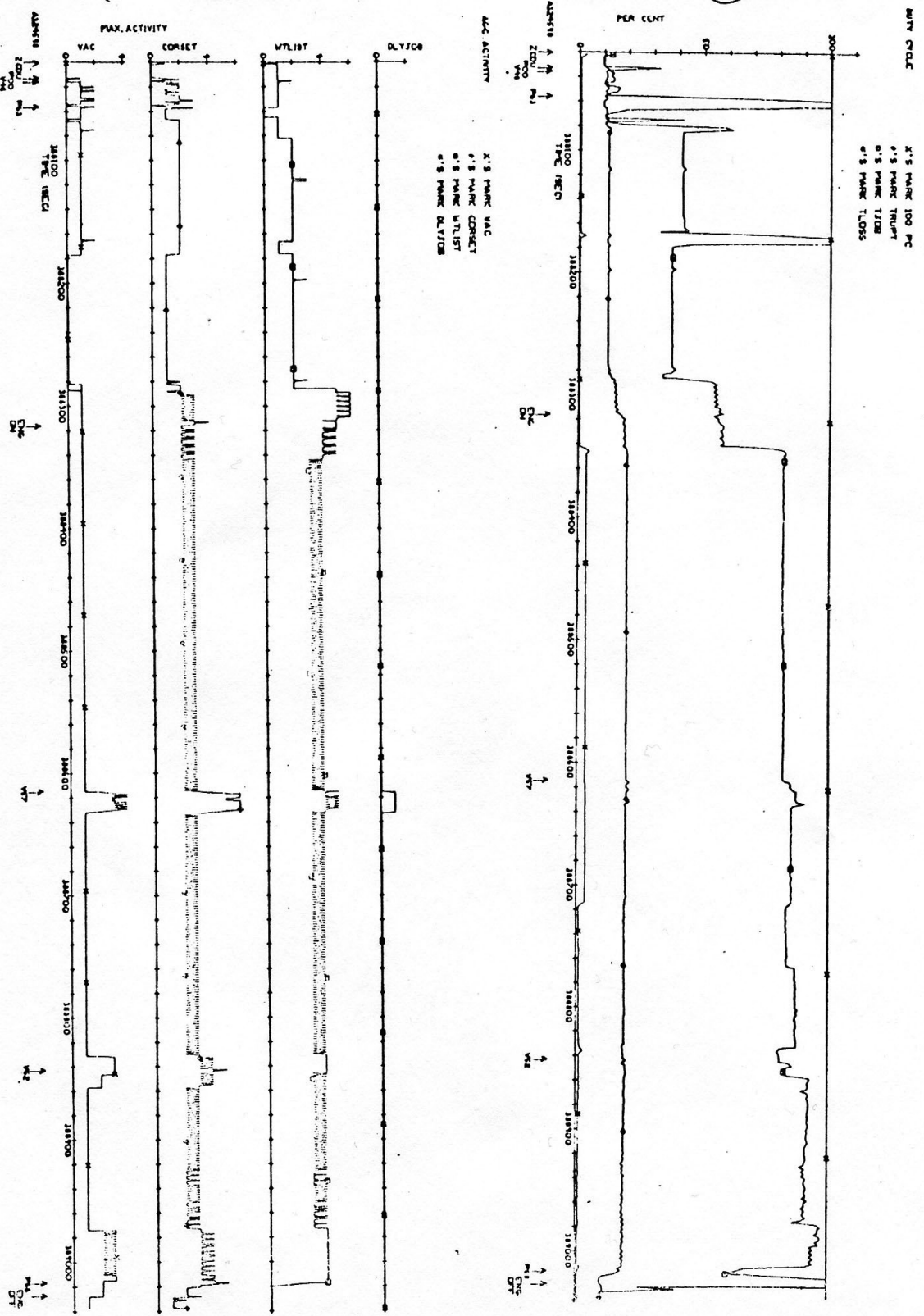
GUIDANCE PERIOD

MARSROT NUMBER 0871⚹375
ZERLINA 16 LANDING WITH PGMIN = 1 SECOND
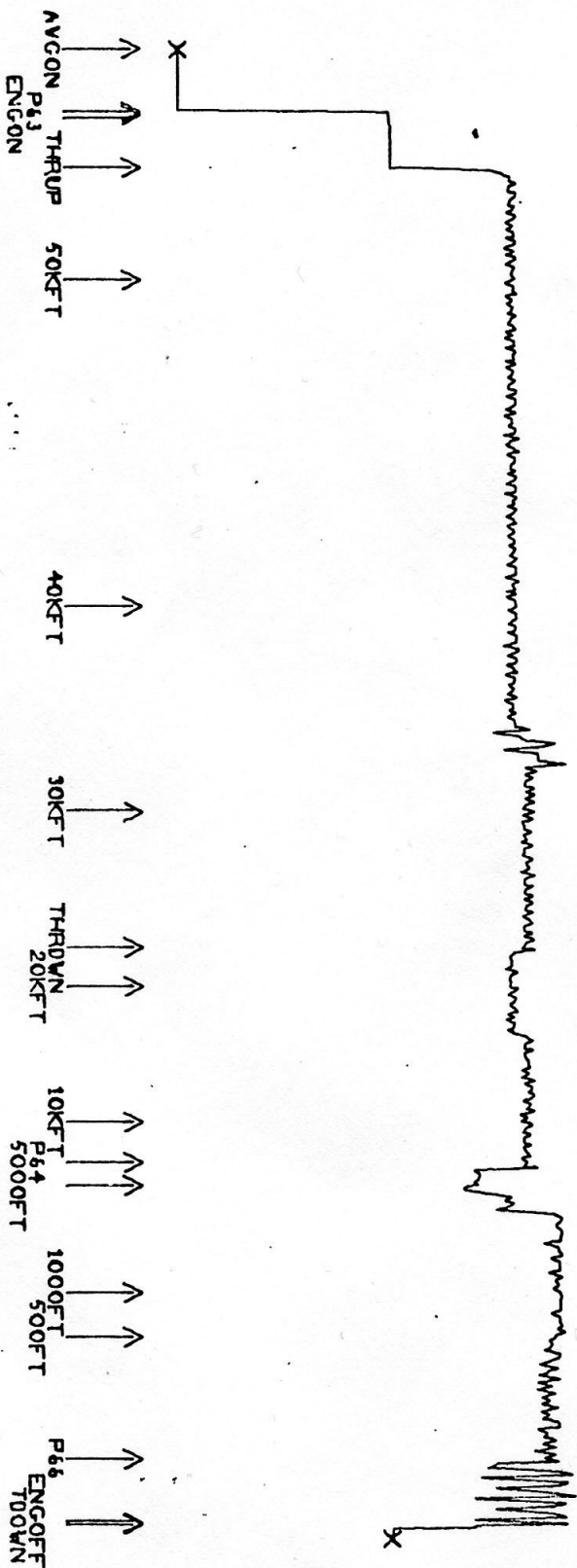
SECONDS

AVGON
P63 THRUP
ENGON
50KFT
40KFT
30KFT
THRDWN
20KFT
10KFT
P64 5000FT
1000FT
500FT
P66 ENGOFF
TDOWN

SECONDS G.E.T.

388300 388400 388500 388600 388700 388800 388900 389000

ZERLINA LANDING: PGMIN = 1 SECOND
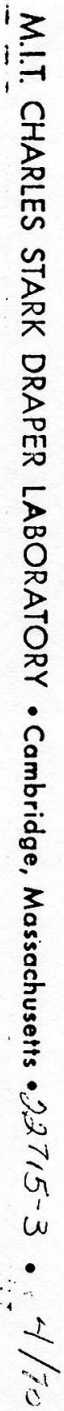
GUIDANCE PERIOD

MARSROT NUMBER 08720472
ZERLINA 16 LANDING WITH 20 PERCENT TLOSS
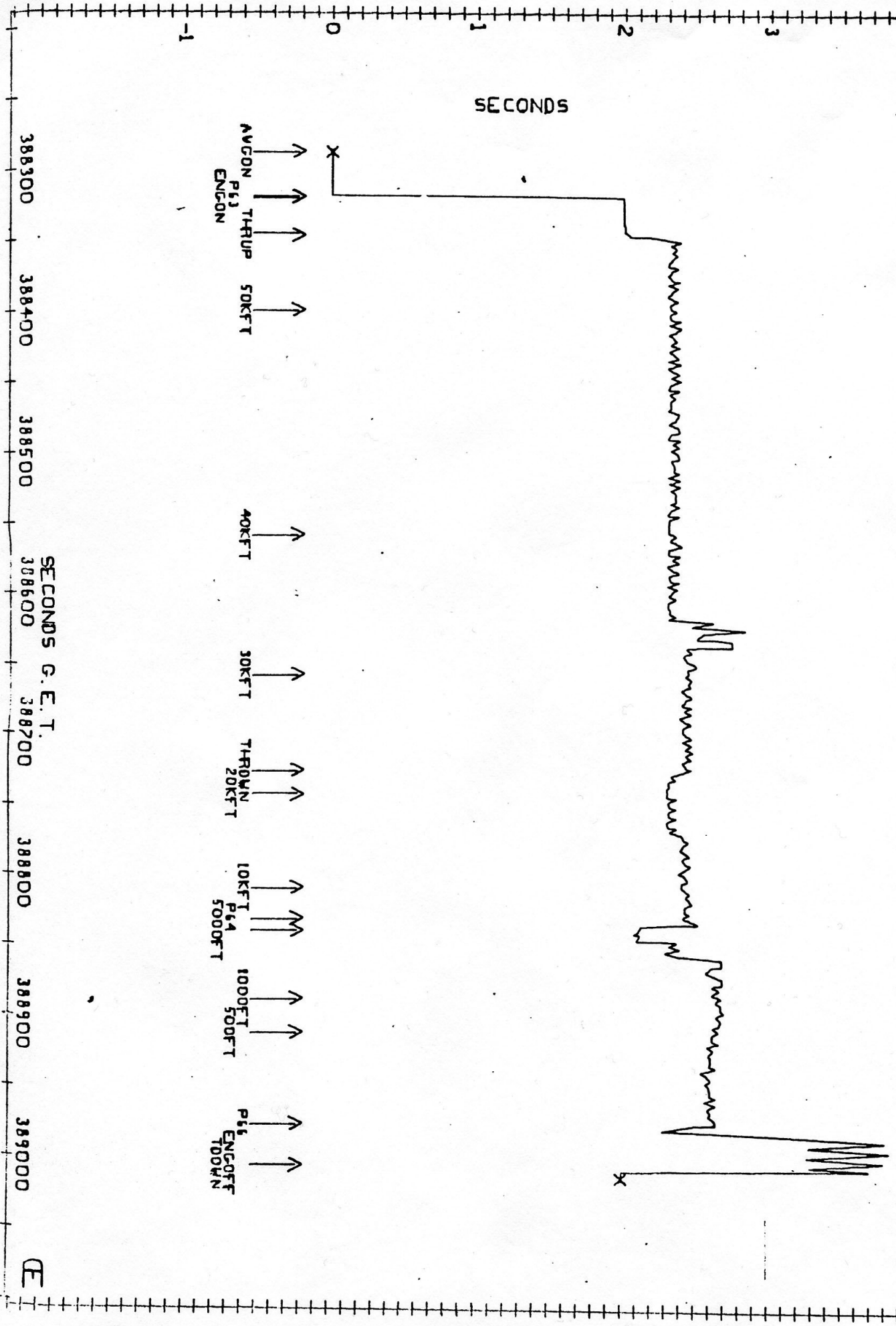
SECONDS

SECONDS G.E.T.

-1   0   1   2   3   4

AVGON
P63
ENGON
THRUP

50KFT

40KFT

30KFT

THROWN
20KFT

10KFT
P64
5000FT

1000FT
500FT

P66
ENG-OFF
TDOWN

388300   388400   388500   388600   388700   388800   388900   389000

E
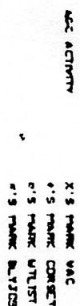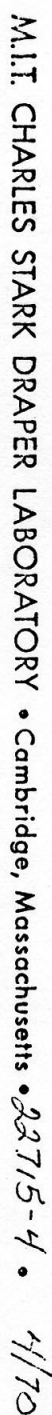
ZERLINA LANDING: 20% TLOSS

GUIDANCE PERIOD

ZERLINA 16 LANDING WITH 30° TLOSS

MAFSROT NUMBER 08822440

(WITH THROTTLE PATCHES)
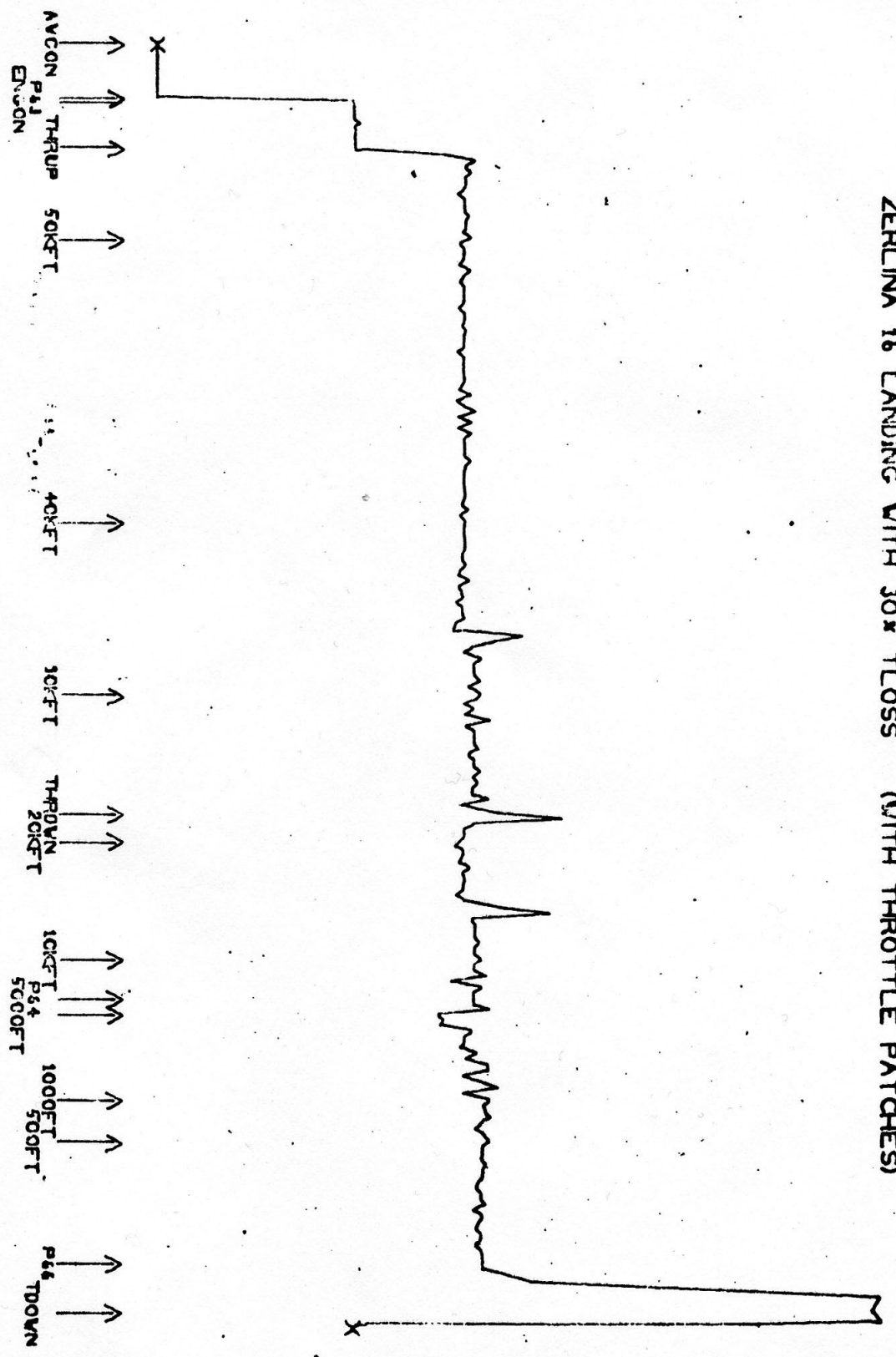
ZERLINA LANDING: 30% TLOSS
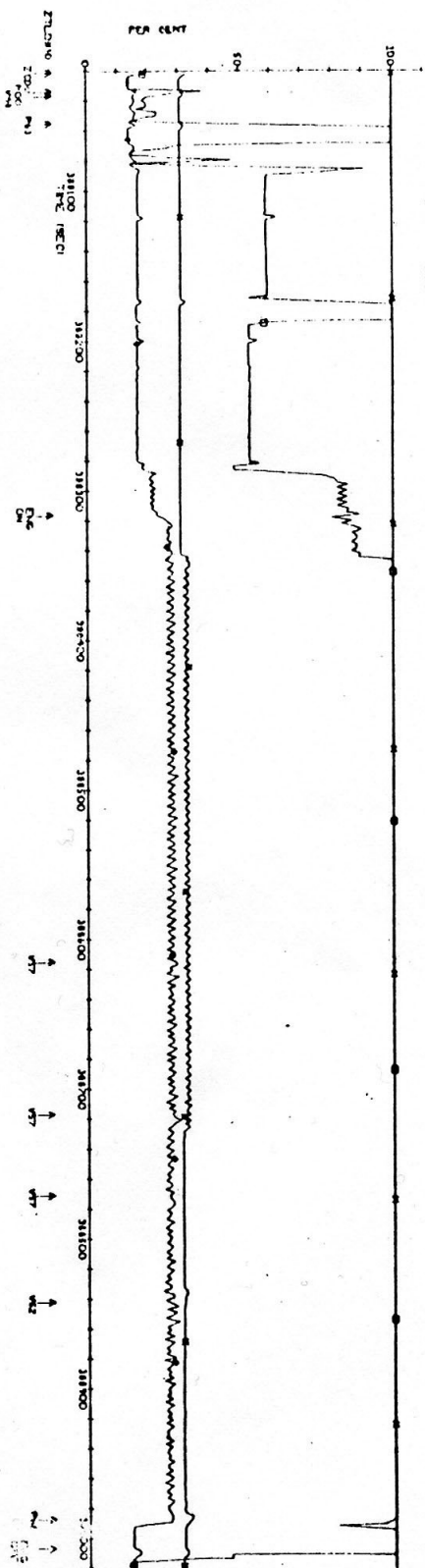
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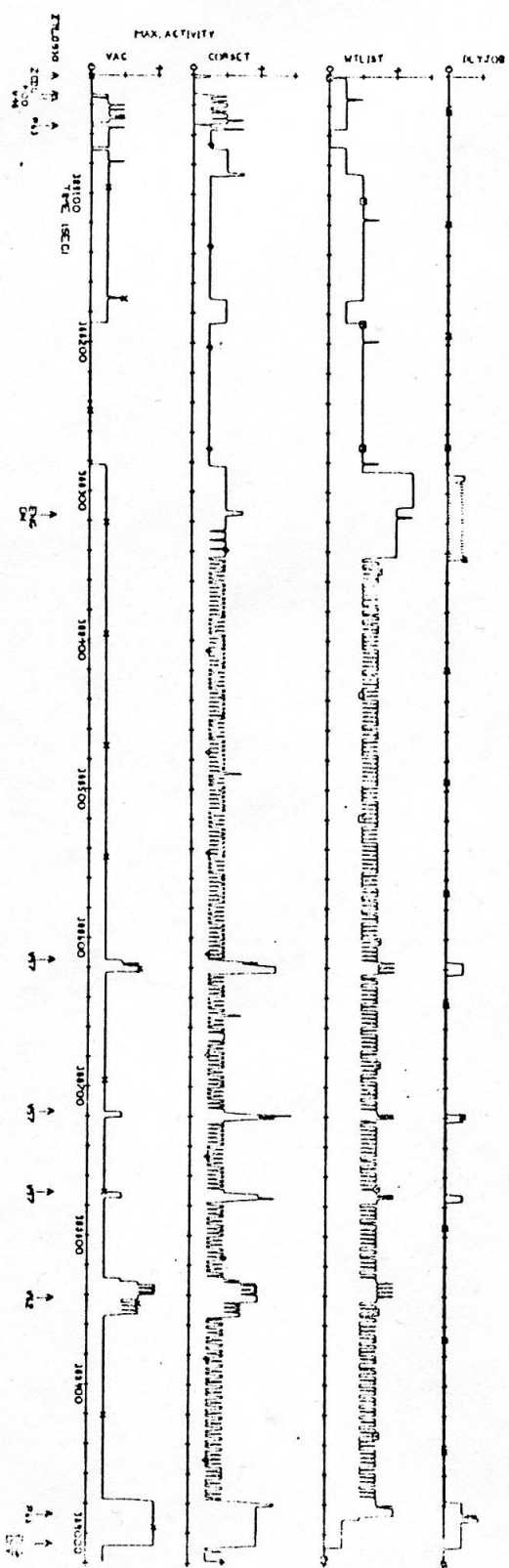
GUIDANCE PERIOD

MARSROT NUMBER 08709172
ZERLINA LANDING WITH TERRAIN MODEL (REVISION 16)
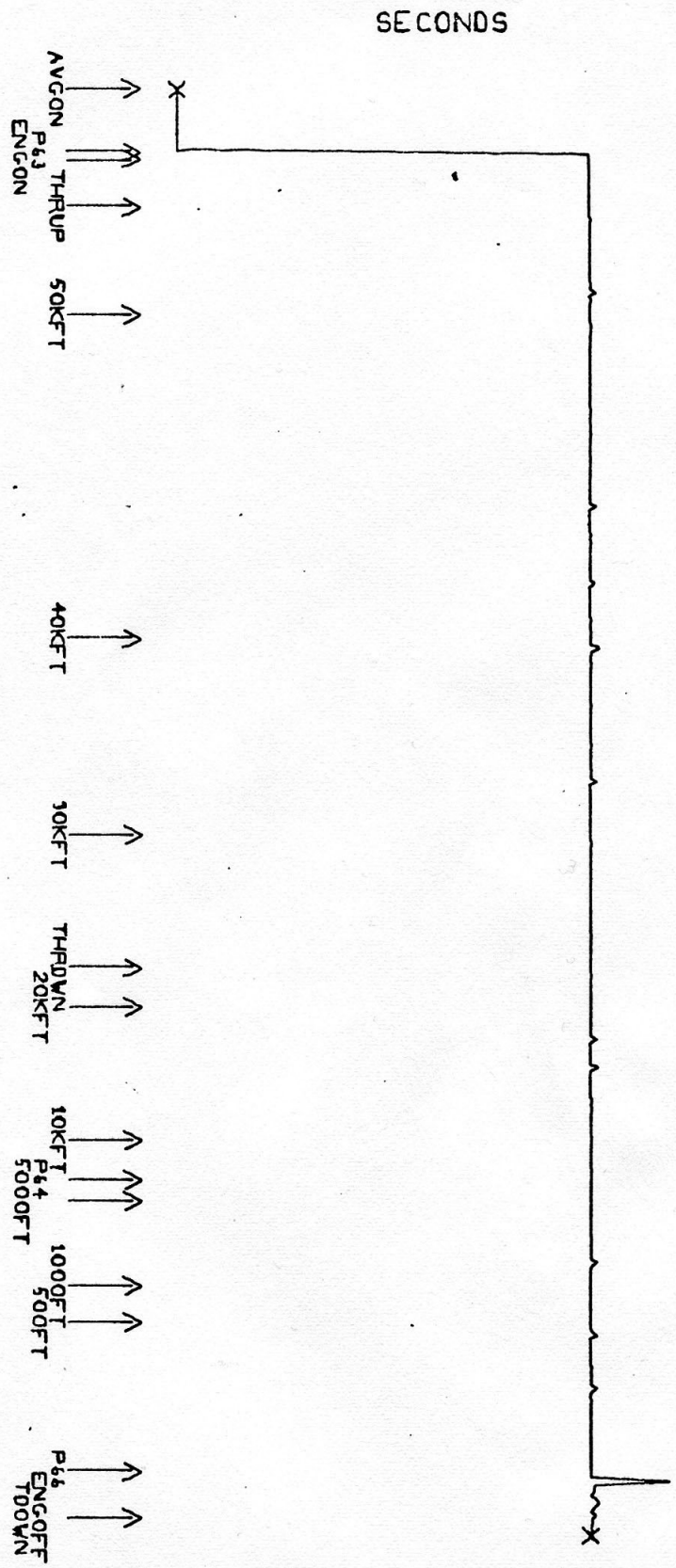
SECONDS

AVG-ON →
P63 ENG-ON THRU-P →
50KFT →
40KFT →
10KFT →
THR-DWN 20KFT →
10KFT →
P64 5000FT →
1000FT 500FT →
P66 ENG-OFF T-DOWN →

-1   0   1   2   3   4

388300   388400   388500   388600   388700   388800   388900   389000

SECONDS G.E.T.

GUIDANCE PERIOD

MARSROT NUMBER 08804261
ZERLINA 16 LANDING WITH REDESIGNATIONS
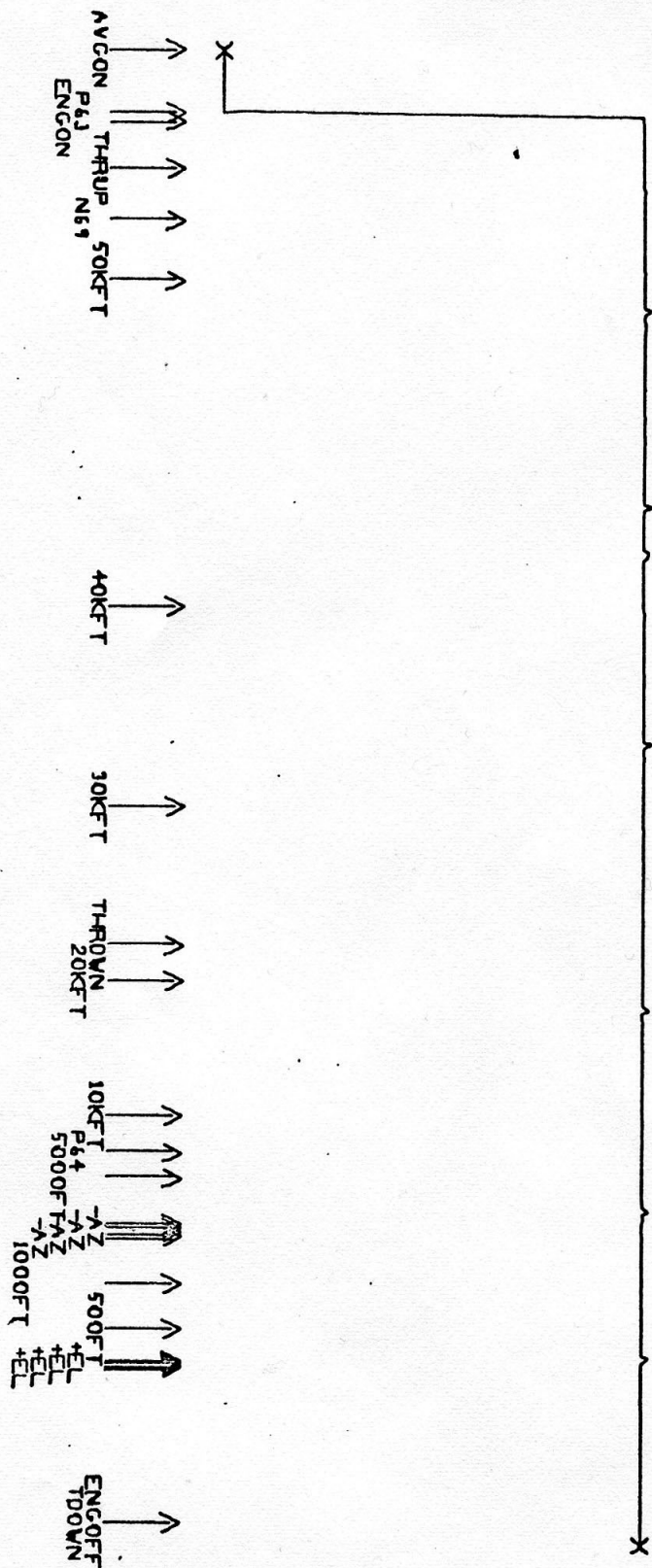
SECONDS

-1 0 1 2 3 4

AVGCON
P&J THRUP N69 50KFT
ENGON

40KFT

30KFT

THROWN
20KFT

10KFT
P64
5000FT
→AZ →AZ
→AZ →AZ
1000FT

500FT
+EL +EL
+EL +EL

ENG-OFF
TDOWN

388300   388400   388500   388600   388700   388800   388900   389000

SECONDS G.E.T.

GUIDANCE PERIOD

ZERLINA LANDING WITH TERRAIN MODEL, 10 × TLOSS, V16

MARSROT NUMBER 0951404
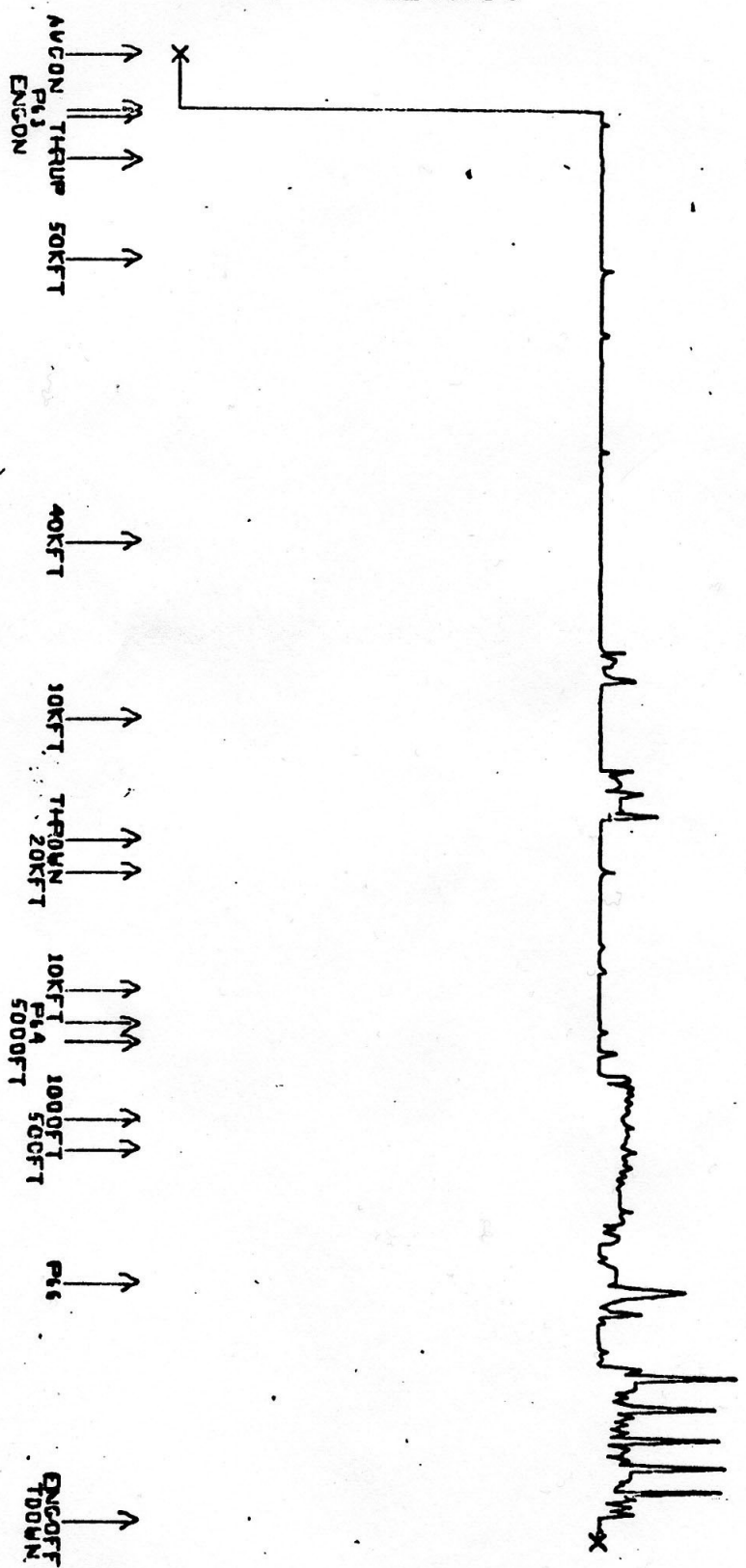
(REVISION 171)

SECONDS

SECONDS G.E.T.

ZERLINA 17: 10% TLOSS TERRAIN V16'S

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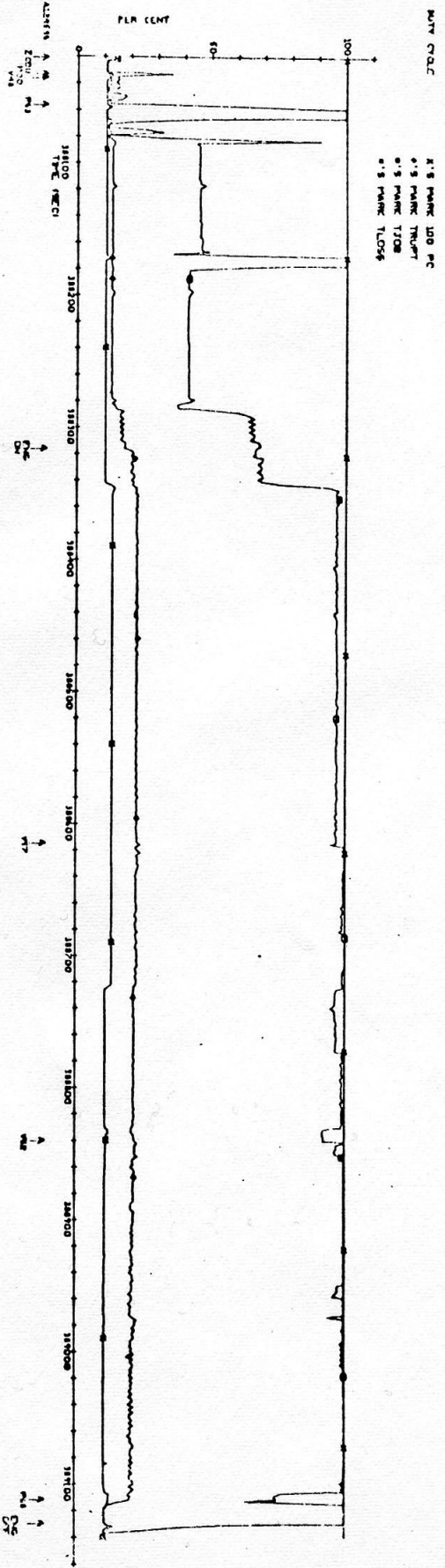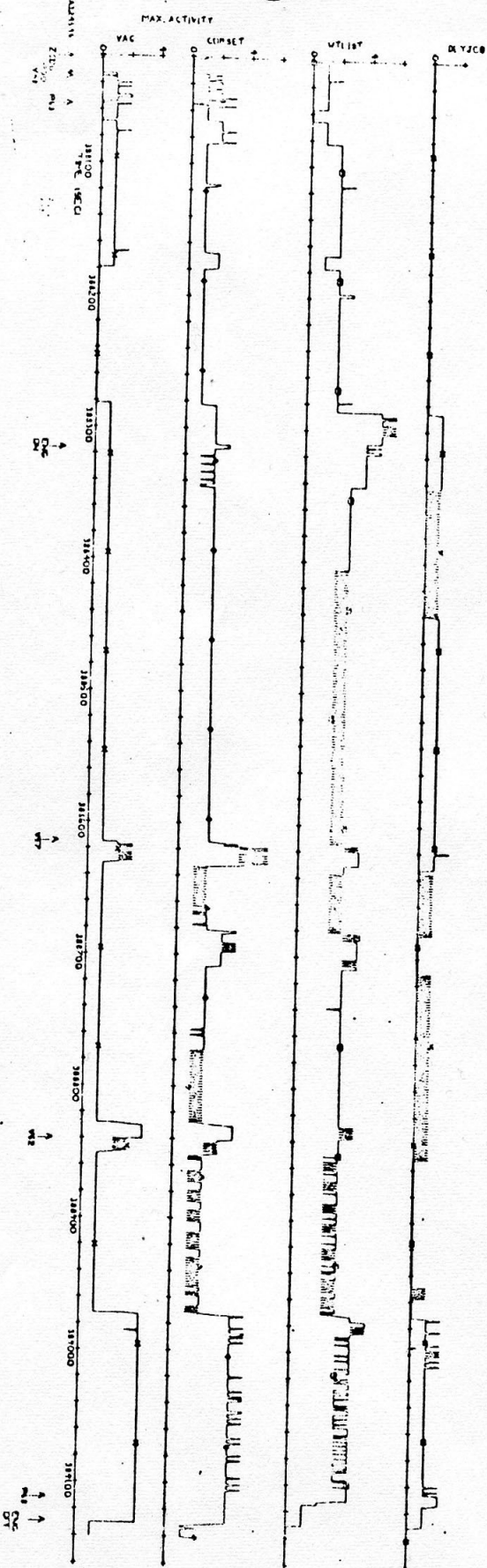
REFERENCES

1. LUMINARY Memo #138, Revision 1, by Eyles, dated March 6, 1970: "Variable Guidance Period Servicer."

2. LUMINARY Memo #139, by Eyles, dated March 4, 1970: "Description of Variable Servicer."

3. LUMINARY Memo #140, by Allan Klumpp, dated March 4, 1970: "A Collection of the Known Manifestations of Time Loss in Luminary Revision 131 and LM131 Revision 001 - Suggested Work-Around Procedures."

4. Working paper by John Norton, TRW, dated March 18, 1970: "Comments on a Variable Guidance Cycle as a LM TLOSS Fix."